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Volume VI June, 1924–26 Number 2

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(Continuing the Journal of the Allied Dental Societies)

A journal of stomatology; devoted to the advancement and dissemination of knowledge pertaining to the teeth and mouth, and to their relations to the body as a whole

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GENERAL ANNOUNCEMENTS

Proceedings of Dental Societies to be Published as Independent Journals Within the Journal of Dental Research

Affiliated dental societies now publish their Proceedings on conditions that make each Society's group of papers, in effect, its own independent journal under the covers of the Journal of Dental Research. Sections may be obtained as reprints, for issuance in separate volumes of Transactions. The import of this development, for the cause of independent professional journalism, will become evident in the successive issues. Information regarding the plan will be given immediately to any society that may request it. All communications regarding the contents of the sections should be addressed to the representatives of the respective societies.

Beginning with this volume the papers published by societies will appear in the main body of the text of each number and will not be segregated at the end in a "section of proceedings." The papers contributed by societies in each number will be regularly listed here.

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Delay in the Publication of this Number

The long delay in the publication of the numbers of this volume has been explained in a circular letter to the subscribers. The effort to publish the delayed volumes for 1924 and 1925 has been discontinued. The numbers of this volume will be brought up to date by giving them the combined year numerals 1924-26.

Important Books Received

The dentist's own book. By C. Edmund Kells, D.D.S., F.A.C.D., 1237 Maison Blanche, New Orleans. 1925: pp. 510; 7 5/8 x 4 5/8 in.; $7.50. C. V. Mosby Company, St. Louis, Mo.

The life and work of James Leon Williams. By George Wood Clapp, D.D.S., 220 West 42nd Street, New York City. With an introduction by C. N. Johnson, M.A., D.D.S., F.A.C.D., President of the American Dental Association, 1925: pp. 299; 7 1/4 x 3 3/4 in. Dentists' Supply Company, New York City.

A REPORT OF FURTHER INVESTIGATIONS ON THE ORGANIC MATRIX IN HUMAN ENAMEL[1]

CHARLES F. BÖDECKER, D.D.S., F.A.C.D.

New York City

The subject I bring before you this evening has so long been connected with my name, and the communications made have been so numerous, that you hardly expect any new developments. This paper is presented, however, from a different angle, in order to explain the reason why investigators and clinicians alike have so long misinterpreted the structure of the enamel as well as the possibility of post-eruptive changes in this tissue. A demonstration of the presence of an organic matrix in human adult enamel will be presented.

The past summer brought me the good fortune of spending a month with Dr. J. Leon Williams, at his home in Maine, where I profited greatly by the many hours we spent together. He had always been decidedly incredulous as to the existence of this matrix in adult enamel, but was open to conviction, if I could furnish irrefutable proofs. Previously he had examined my specimens of this structure minutely, even making photomicrographs of it, but still was not entirely convinced of the truth of my assertion. It was his contention that decalcification had not been carried far enough and that the structure I showed in my slides must be brittle and inorganic in nature. He demanded the proof which I will repeat here tonight at the conclusion of this paper. When this proof was furnished, then and not till then was Dr. Williams convinced. It was good to hear his: "That settles it," for it has been a long, long controversy, but one worth ten times the labor spent to win such an ally. He again infused me with enthusiasm concerning the importance of the existence or non-existence of a matrix in the adult enamel. There is no doubt that, as Dr. Williams says, the enamel is the first and strongest barrier against

[1] Read at the annual meeting of the International Association for Dental Research, Columbia University Club, New York City, December 7, 1923.

caries, for when that fails, the decay of the dentin is rapid and the life of the pulp is endangered. Therefore, in the fight against caries, our efforts have to be directed towards perfecting our knowledge of the enamel, and to this end it is of prime importance that the structure and chemical nature of this important tissue be settled.

The old question, whether general conditions of the patient may affect the enamel, was dismissed years ago by Tomes (12) and Black (3), who asserted that this tissue is entirely inorganic in nature, and consequently no circulation could possibly take place within its confines. If this were really the case, then further argument on this point would be useless. Numerous investigators, however, stimulated by repeated clinical experience in noting that the health of a patient does affect the teeth, ill-health making them prone to caries and vice versa, persisted in their study of the problem. Bunting and Rickert (6) proved that enamel was permeable; Caush (7) and Von Beust (13) showed the possibility of forcing stains from the pulp chamber through the dentin into the enamel. The former experiments do not necessarily presuppose the existence of an organic matrix, for the enamel might be permeated by minute channels through which fluids could pass. Von Beust, and the author (5), however, claim that an organic matrix exists.

The group of investigators who believe that the resistance of the enamel varies according to the health of the patient, have divided into two groups, one claiming that this tissue may be calcified or decalcified by the oral fluids, the other, as yet in the minority, that these changes are induced by the internal circulation in the tooth itself. The author believes that the second view is the correct one, that is, that all of the changes that take place in the enamel are caused by means of the intra-dental circulation, which has its origin in the pulp and passes through the dentin into the enamel. The first requirement to make this phenomenon possible is the existence of an appreciable organic matrix in the enamel having intimate connection with the dentin. I say "appreciable," even though the weight of this organic matrix, in comparison to the weight of the mineral constituent, may be small. Dr. William J. Gies has pointed out to me that the weight of the nerves of the arm, for instance in comparison to that of the muscles and bones is very slight, yet the absence of these very

nerves would make this member useless. The argument, therefore, that the organic constituent of the enamel is so minute that it is impossible to fulfill any function, is not tenable. However, it is not my belief that the amount of organic matter in the enamel is small; on the contrary, it is my purpose to prove to you that, in volume, it is almost equal to that of the mineral portion. Our understanding of the important problem of caries of the enamel will be greatly influenced by the fact that an organic matrix exists. How can we ever hope to approach a solution of this problem, if we do not even know the exact nature, both histologically and chemically, of that tissue which forms the foremost barrier against the most prevalent disease to which man is subject?

With this question in view, I am going to go back to the very beginning of my work, and will bring proof upon proof of my contention that adult enamel contains an organic matrix, until the consensus of opinion agrees or disagrees with me. Up to the present, American investigators have done neither. Fleischmann (8) gives me credit for being the first to prove conclusively the presence of this organic matrix by my celloidin decalcifying method. Baumgaertner (2), Andresen (1), and Rygge (11) also corroborated my findings. The first point to be taken up is the morphology of the enamel and even that phase of the question will not, by any means, be exhausted in this paper. Tonight I simply wish you to certify the existence or non-existence of a matrix in the enamel. The chemical nature of this tissue is a matter for the chemist to decide. I claim it is not mineral, and advanced three proofs before the American Dental Association at this year's meeting in Cleveland, as ground for my contention that it is organic.

Von Bibra's well-known analysis of enamel, made in 1844—seventy-nine years ago—indicates the amount of organic matter as varying between 3 per cent and 5 per cent. I wish to advance three reasons why these figures, in my opinion, are incorrect and do not give a true representation of the ratio between the organic matter and the inorganic matter. Concisely expressed, my reasons for this statement are these (I–III):

I. Only that part of the enamel poorest in organic matter was selected for analysis.

II. Water, a normal constituent of organic matter, is not included in the analysis.

III. The percentages of organic matter and mineral matter are reckoned by weight instead of by volume.

I. Only that part of the enamel poorest in organic matter was selected for analysis. It is difficult to distinguish macroscopically between

FIG. 1. Organic matrix of human *adult* enamel, prepared by the acid celloidin decalcifying method. The entire thickness of the enamel is shown, all dentine having been removed. Note the greater amount of organic matter in the enamel near the surface of the tooth (at the right) and at the dento-enamel junction (at the left). The middle third, which is commonly used for analysis, is seen to be poorest in organic matter. The magnification is so low that the individual enamel rods can only be just decerned.

enamel and dentin, and, as the slightest amount of dentin adhering to the piece of enamel to be analysed would make the analysis unreliable, great care was naturally taken to remove all traces of dentin. This precaution had to be carried to such an extreme that even portions of enamel at the dento-enamel junction were removed. But it is the inner third of the enamel nearest the dentin that contains the greatest amount of organic matter, as will be proven by my photo-

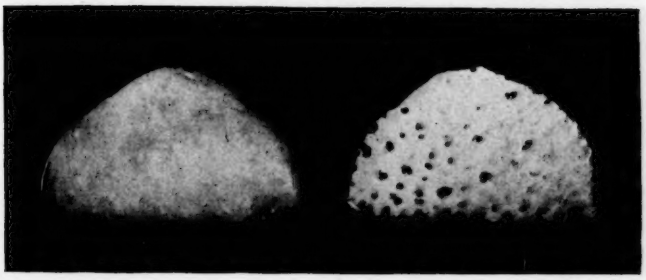

FIG. 2. A stone and sponge of approximately the same shape and volume. The stone is comparable to the inorganic constituents of the enamel and the sponge to the organic matrix. The dry sponge is less than 1 per cent of the weight of the stone, proving that an organic matrix in the enamel of 3–5 per cent is equal in *volume* to the inorganic constituent and therefore has sufficient bulk to carry on a circulation.

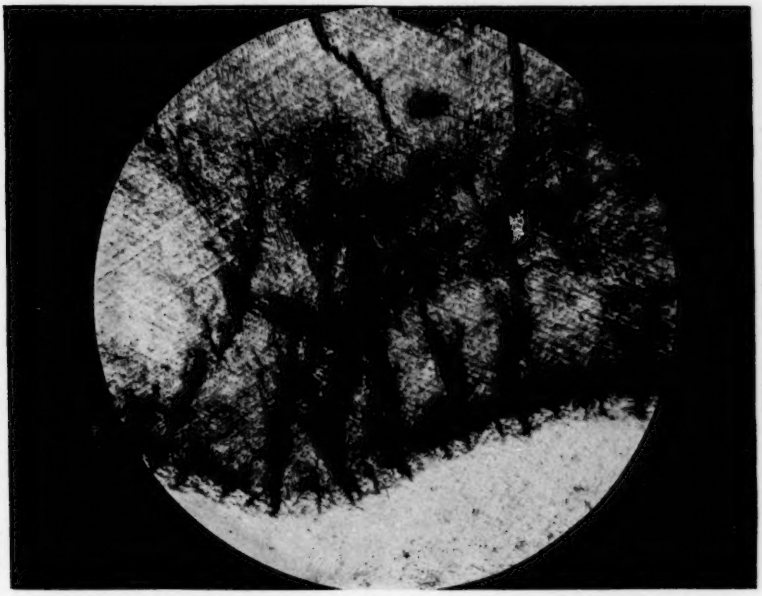

FIG. 3. Ground section of enamel (above) and dentine (below) as ordinarily prepared, i.e., not decalcified, showing numerous tufts and one enamel lamella. These lamellae had been regarded as cracks in the enamel, but the author has proven, by special methods, that they consist of leaf-like, organic structures in connection with the tubules of the dentine.

micrographs, and this portion did not enter the chemical analysis. The surface of the enamel was also thoroughly scraped in order to remove all traces of Nasmyth's membrane. Here again a part of the enamel rich in organic constituents was removed. How much the percentage of organic matter would have been increased by including

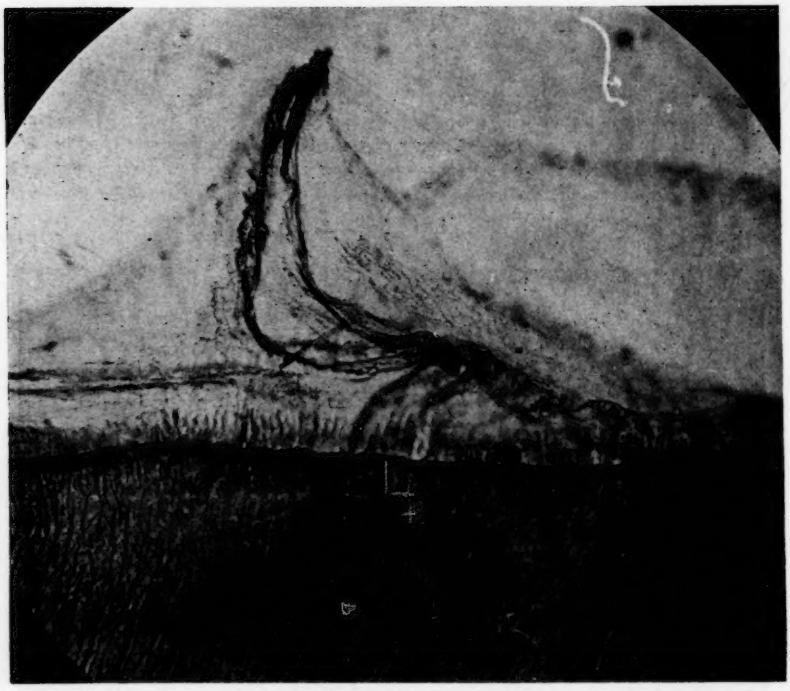

FIG. 4. Ground section of enamel (above) and dentine (below), decalcified under the coverglass and photographed with ultraviolet light. The mineral constituents of the enamel have been dissolved, leaving a delicate matrix held up by a sturdy enamel lamella. This manner of procedure does not retain the matrix in situ. (*Dental Review*, 1906.)

these two areas is difficult to determine. That it would have been appreciable, however, is proven by a study of my sections, which show an abundance of organic matter at the inner and outer thirds of the enamel, while the middle third seems considerably poorer (*fig. 1*). Therefore, I believe I am right in assuming that only that part of the enamel, poorest in organic matter was selected for analysis.

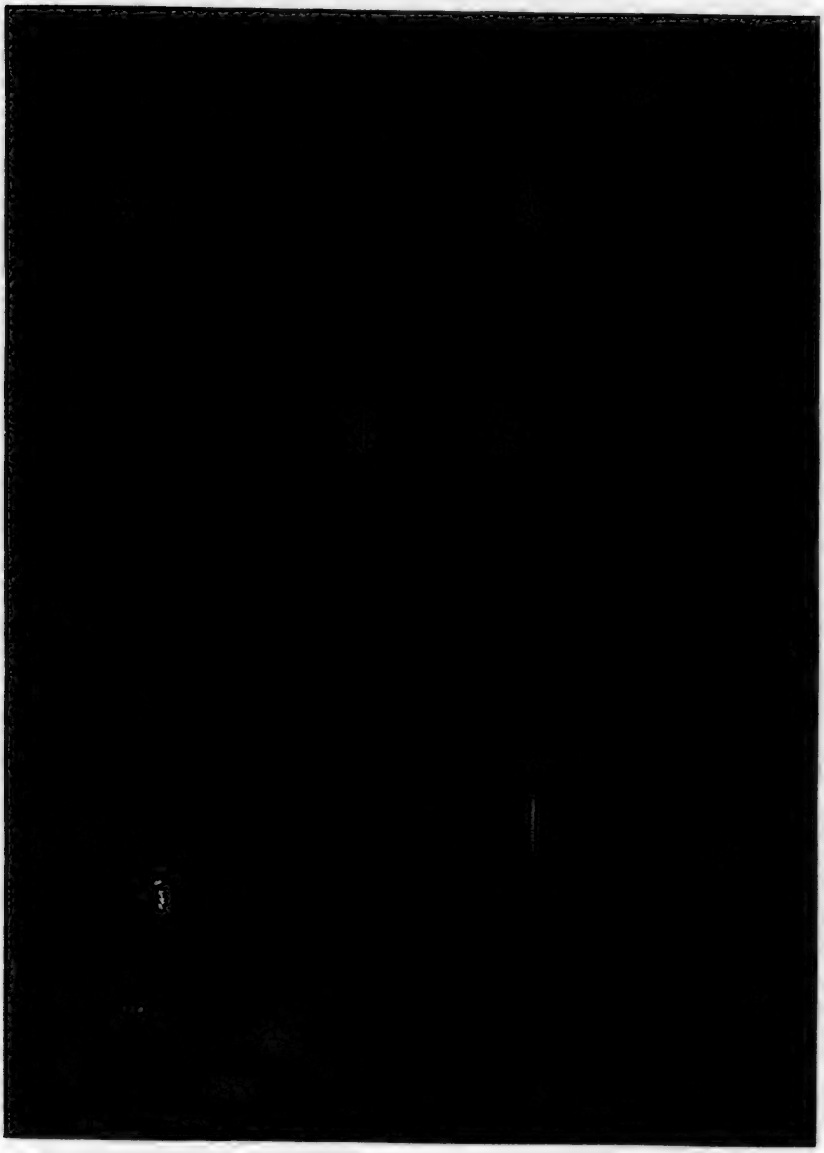

FIG. 5. Ground section of enamel and dentine photographed with ultra-violet light, clearly showing a forked dentinal tubule passing into a broad enamel lamella.

II. *Water, a normal constituent of organic matter, is not included in the analysis.* I am not trying to convince you that water should be classed as an organic compound; it is my contention, however, that it should be included in the chemical analysis, if we are to have a true conception of the ratio of the weights of the constituent parts of the enamel. It must be retained for two reasons: (a) It is present under

FIG. 6. Human, *adult* enamel decalcified by the author's celloidin decalcifying method, showing the organic matrix. *All* mineral matter has been removed. The section from which this photomicrograph was made by ultra-violet light is 2 microns (2/25000 of an inch) in thickness. It shows an area of gnarled enamel, each bundle of rods frequently changing their direction, giving this tissue its great strength to withstand the stress of mastication.

normal conditions, and (b) there is a higher percentage of water in practically all cellular structures than in mineral matter. Let me explain these two points.

(a) *Water is present under normal conditions.* Water enters into the composition of all organic materials. Muscle, for instance, contains 80 per cent of water. Would we obtain a true conception of

the volume of this tissue if we disregarded this bulk of water? Protoplasm contains 68 per cent to 72 per cent of water, and even if only a small portion of it is extracted, the mass is no longer normal protoplasm. The organic matrix of the enamel, judging from similar analogies, has probably as much as 75 per cent of water in its normal condition when the tooth is in function. In removing the water, before the chemical analysis, we therefore reduce the weight of the residue of the normal organic matrix by 75 per cent.

(b) *There is a higher percentage of water in organic matter than in mineral matter.* To exclude water, the weight of the organic matter is

FIG. 7. Human, *adult* enamel, prepared like that shown in *fig.* 6, depicting the enamel rods cut longitudinally to their axis. Organic matter only is seen in the photomicrograph. Such specimens easily give the impression of "enamel fibers" (described by C. F. W. Bödecker in 1878) lying between the rods. The delicate transverse striations of the individual rods are clearly seen and proven to be organic in nature.

reduced proportionally much more than that of the mineral. A simile will explain the point in view. This stone, which we will say represents the mineral content of the enamel, weighs when moist 34.345 grams. After being thoroughly dried, it weighs 34.339 grams, registering a loss of 6 milligrams; this is the amount of water it can take up and represents less than 1/5000 of its weight. To remove this infinitesimal amount of water *does not* materially affect the weight as a whole (*fig. 2*). This sponge, on the other hand, representing the organic matrix of the enamel, weighs 0.298 gram when dry. When

moist, however, it weighs 2.717 grams, indicating an increase of 2.419 grams, representing an increase of over *ten* times its dry weight. To remove this relatively great amount of water, *does* affect the weight as a whole.

In drying a piece of enamel for chemical analysis, we remove, at least 5 per cent of atmospheric moisture from the mineral and approximately 75 per cent of inherent water from the organic matter. If,

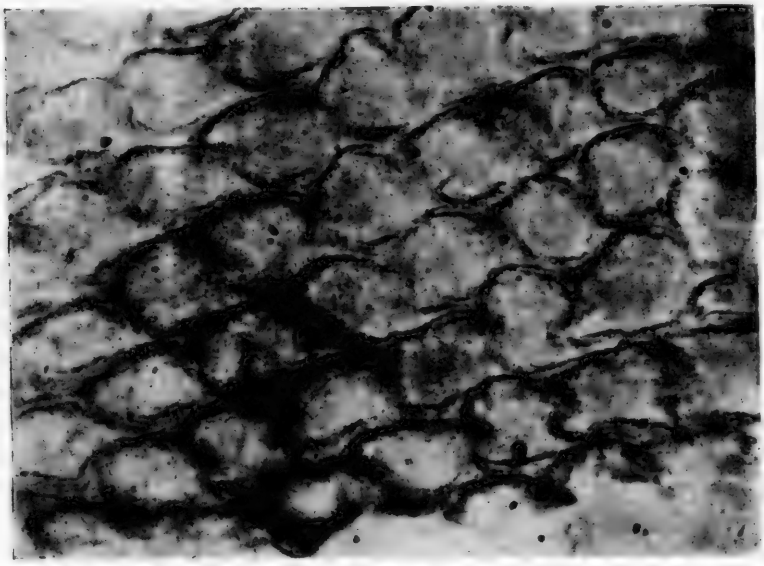

FIG. 8. Human, *adult* enamel treated by the author's celloidin decalcifying method, showing the enamel-rod sheaths in transverse section. In certain areas the sheaths have separated somewhat from their neighbors, clearly proving that each enamel rod is enclosed in its individual sheath. (*Dental Review*, 1906.)

therefore, as claimed under (a), water is normally present in organic matter, and if, as pointed out under (b), organic matter contains a much greater quantity of water than mineral matter, it follows that, in order to have a true conception of the relative weights of organic and inorganic matter in enamel, water should be included in the analysis. The analysis of Von Bibra for *dry enamel* gives organic matter 3.59 per cent; mineral matter, 96.41 per cent; for *moist enamel*,

however, 75 per cent of the weight of the organic matter has to be added to the one side of the analysis and only 5 per cent to the mineral content. The relative quantities would then be as follows: *moist enamel*—organic matter, 5.84 per cent; mineral matter 94.16 per cent. This analysis was selected because it showed the lowest percentage of organic matter. Other results specifying 5 per cent of

FIG. 9. Incinerated human, *adult* enamel. In the left-hand illustration, the mineral matter, constituting the body of the enamel rods, is seen in transverse section. The enamel-rod sheaths and cement substance being organic have been consumed by the heat, leaving clearly defined spaces around the hexagonal prisms. The fact that heat consumed the sheaths and cement substance was the fourth proof of their organic nature. In the right-hand illustration, the rods are noted in longitudinal section. The transmitted light passes between the rods, showing spaces previously filled by the organic enamel-rod sheaths and cement substance.

organic and 95 per cent of mineral matter would, when the normal content of water is added, give 8.06 per cent of organic and 91.94 per cent of mineral matter. These figures suggest more truly the proper ratio of the *weights* of the constituents of normal adult enamel.

III. *The percentages of organic matter and mineral matter are reckoned by weight instead of by volume.* Again a simile will serve to make

the meaning clear. This stone and this sponge are approximately of the same size, but the difference in their weights is enormous (*fig. 2*). The stone weighs 34.339 grams and the dry sponge, 0.298 gram. This means that the stone, even though it is the same size as the sponge, is over 115 times heavier. If both of these structures were incorporated into one mass, the percentage of the weights would be as follows: Stone more than 99 per cent; sponge less than 1 per cent. This comparison of the enamel to a calcified sponge, is not so far fetched as may appear, for most sponges have calcium or a silicate deposited in their organic matrix. The zoologist would not think of disregarding the presence of this organic matrix. He knows that although the percentage of weights of the two substances is very unequally divided, yet the *volume* of the organic matter is almost equal to that of the mineral. The physical conditions in the enamel are very similar to those in the sponges, inasmuch as in each an organic matrix is impregnated with mineral matter, the only difference being that in the enamel, the matrix is exceedingly finely divided and of such delicate structure that it falls to pieces when the mineral matter is extracted under ordinary conditions.

To return to Von Bibra's chemical analysis of the enamel, which states approximately 3.5 per cent and 96.5 per cent as the respective weights of the organic matter and the mineral matter, we receive the mental picture of this tissue as consisting almost entirely of mineral matter, the 3.5 per cent of organic matter being regarded as a negligible quantity. But remember, this sponge, being the same size as the stone, represents less than 1 per cent or 1/115 of the weight of the latter. This simile should definitely assure us that the 3.5 per cent of *dry* organic matter—about 1/28 of the weight of the enamel—must be a sufficiently large quantity to maintain a circulation.

In closing, gentlemen, I wish to suggest that the foregoing proves that the 3 per cent to 5 per cent of dry organic matter, noted in the chemical analysis, is not "too small an amount to be of much significance" (Tomes). If it were possible to ascertain the relative volume, that is the space it occupies in comparison to the mineral matter, the quantity of the organic constituent would be almost equal to that of the mineral.

These lantern slides (*figs. 1–9*) have for the greater part been newly prepared, partly with the assistance of Dr. J. Leon Williams. The convincing part of the proof of my assertion, however, is the demonstration of this matrix under a special microscope, kindly lent me by Dr. Williams, allowing the observer to manipulate and bend in all directions this soft, flexible, reticular structure. The analogy of this matrix to a sponge-like mass will strike all of you. It was the final proof which convinced Dr. Williams, and I hope for like success with the members of this Association.

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(6) Bunting, R. W., and Rickert, U. G. 1915 *Journal of the National Dental Association*, ii, p. 347.
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(8) Fleischmann, L. 1910 Ergebnisse der gesammte Zahnheilkunde, i, p. 2.
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(10) Pickerill, H. P. 1912 Dental Caries, Bailliere, Tindall, and Cox, London.
(11) Rygge, J. 1916 *Norsk Tandlaegetidende*, vii.
(12) Tomes, Charles. 1904 Dental Anatomy, J. and A. Churchill, London.
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ADDENDUM

At the meeting of the New York Section of the International Association for Dental Research, held in New York City on the 7th day of December, 1923, the matrix of the enamel was demonstrated by Dr. Charles F. Bödecker. We, the undersigned, hereby certify that we have examined this decalcified matrix of human adult enamel under a microscope. We have teased it with needles and find that it is soft, elastic, sponge-like and reticular in nature. Physically it does not show the characteristics of mineral matter, no trace of brittleness or hardness being evident in any of the specimens of enamel matrix pre-

sented to us to-night. What its true nature may be is a matter for the chemist to determine.

(Signed) William J. Gies, Theodor Blum,
J. Leon Williams, F. C. Kemple,
George Wood Clapp, J. Lowe Young,
Victor H. Jackson, A. Berger,
Milo Hellman, Paul R. Stillman,
Bissell B. Palmer, Jr., Herman E. S. Chayes,
Arthur H. Merritt, Andrew J. McDonagh,
M. L. Rhein, L. M. Waugh.

In the discussion, Dr. Gies suggested that until it is shown directly that the matrix contains or is free from protein matter, a reasonable scientific doubt regarding the relationship of the matrix will persist. He said it would give him pleasure to endeavor to determine whether protein is present. See the paper, in this issue, on page 143.

THE PRACTICAL SIGNIFICANCE OF THE ORGANIC MATRIX IN HUMAN ADULT ENAMEL[1]

CHARLES F. BÖDECKER, D.D.S., F.A.C.D.

Associate Professor of Dental Histology and Embryology, School of Dental and Oral Surgery, Columbia University, New York City

The presence of an organic matrix in human adult enamel may be regarded as proven though not universally accepted. This matrix was first noted by my father in 1878 and described as a network of organic fibers, lying between the enamel rods. His findings were corroborated by W. W. Andrews. Later, they seemed to be definitely refuted by the excellent photomicrographic work of J. Leon Williams, at a meeting of the First District Dental Society, in 1896. A number of the Fellows here to-night may remember the heated discussion which took place at that time. After this event, my father gathered together the findings of his researches of twenty-four years in the "Anatomy and Pathology of the Teeth," saying that the truth would win in the end, and rather forlornly turned his back upon further work in this field.

When I began to study the microscopic structure of the dental tissues, my father advised me not to read his work, but to strike out upon an independent course. This train of thought showed his confidence in the validity of his findings. He wanted me to approach the problems in my own way and so develop an individual point of view. The wisdom of this course has been justified by the results obtained, and I can truthfully say that even to the present day, I have read but little of his work.

During the author's training in the natural sciences, covering a period of seven years in the Universities of Berlin and Jena, he also received a thorough schooling in the preparation of specimens for

[1] Read at a meeting of the New York Academy of Dentistry, New York City, December 17, 1924. The references to literature, illustrations, and specimens are practically the same as those of the preceding paper in this issue, page 129.

microscopic examination. His first findings, accompanied by numerous photomicrographs proving the presence of the organic matrix in the enamel, were published in the *Dental Review* in 1905 and 1906, together with an exact description of the rather complicated methods for the special examination of the enamel. In 1911, an article upon the "Nutrition of the Enamel" was published in the *Dental Cosmos*. To link together the two words "nutrition" and "enamel" was, thirteen years ago, sufficiently revolutionary to insure that the article would be read by but few. And so it was, for it received, for a long time, neither corroboration nor refutation.

The number of investigators, however, who since then believe in the presence of an organic matrix, has been steadily increasing. These authorities include Fleischman, Von Beust, Caush, Mummery, Baumgaertner, Rygge, and Andresen. These men used various means of preparing the enamel to demonstrate the organic matrix, some by staining in the routine manner, some by the injection of dyes from the pulp chamber, and still others by the use of my celloidin decalcifying method (Fleischmann, Baumgaertner, Rygge, and Andresen). The latest contribution on this subject is that of Malleson, who has also used celloidin as a decalcifying medium without any knowledge of my method. His results were recently published in the *British Dental Journal* (May, 1924), and it is gratifying to note that his photomicrographs resemble mine in a marked degree.

I will not go into a technical description of the celloidin decalcifying method, which I devised for structures containing minute quantities of organic matter, but will give you only the fundamentals involved. I have used this method not only for the enamel but also for the decalcification of sponges. The medium used to extract the mineral salts from the enamel is an acid celloidin. Celloidin is employed in the microscopic technique to embed soft tissues in order to section them on the microtome. In its fluid state, it is of a thick syrupy consistency and when allowed to solidify, its hardness closely resembles that of cartilage. The principle involved in the decalcification of the enamel by this method is the following: A piece of this tissue is placed in acid celloidin; the acid starts to extract the mineral matter from the enamel, and the celloidin, which as mentioned above is of a thick syrupy consistency, immediately takes the place previously occupied

by the extracted mineral matter, thus buoying up the remaining delicate organic cement substance. In this way the organic matrix of the enamel is retained in its approximate shape and position, while the inorganic salts are removed by the acid.

I was often puzzled by the fact that it was impossible to demonstrate the presence of the organic matrix in the enamel by decalcification in an aqueous solution of acid. If it is present in the enamel, it should also be possible to find it after the calcium salts have been removed in the ordinary manner. Time and time again, I have placed a tooth in weak acid and watched the enamel slowly disintegrate, accompanied by an evolution of CO_2. It only left a finely divided sediment in the bottom of the vessel. Why does one obtain a fairly homogeneous organic matrix when the enamel is decalcified by my celloidin decalcifying method? Let us compare the enamel to a brick wall. The bricks represent the enamel rods and the cement between the bricks is analogous to the organic cement substance between the enamel rods. Each brick in this hypothetical wall, however, has gun powder concealed in it. Suppose it is our intention to demolish this wall by successively exploding the gun powder concealed in each brick. Under such conditions what will happen to the cement which held the bricks together? Will we be able to find it in the mass of debris? Will we have a mesh-like structure of cement, showing the position occupied by the destroyed bricks? No, nothing will remain of the cement structure but powder. Let us now turn to the enamel and examine how the addition of acid acts upon the mineral content of this tissue. The acid attacks the calcium salts of the enamel rods, instantly setting free a great amount of CO_2. This liberation of CO_2 is accompanied by an almost explosive force, for the field of action of this chemical decomposition is closely confined within the organic matrix. Just as the exploding brick bursts the cement which encloses it, so does the evolution of the CO_2 disrupt the delicate organic matrix which envelops the enamel rods. All that remains of the organic matrix is a finely divided sediment which collects on the bottom of the vessel. We can therefore readily understand why it is impossible to obtain a homogeneous matrix of the enamel by decalcification in a watery solution of acid.

Many clinicians have the conviction that the enamel of newly

erupted teeth is not as highly calcified as it is later in life. If this be true, by what means are the inorganic salts deposited in this tissue after the eruption of the teeth. The two theories as to the manner in which this hardening of the enamel takes place, can be termed (a) the mechanical and (b) the vital.

(a) The *mechanical deposition* of inorganic salts in the enamel, as maintained by Bunting, Rickert, Walkhoff, and others, proceeds in the following manner: The calcium salts, dissolved in the saliva, pass through Nasmyth's membrane covering the tooth, and are precipitated and deposited in the enamel, thus hardening its structure. Both Bunting and Rickert have conclusively proven the permeability of the enamel to fluids, and it is possible that the crowns of teeth may thus be hardened after their eruption.

(b) The *vital theory* maintains that the deposition of the inorganic salts, to harden the enamel, comes from the general circulatory system, i.e., the blood plasma, by way of the dental pulp and dentin. I claim that the organic matrix, with its intimate connection with the vital fluids of the dentin, forms the channels of communication and distribution for the calcium salts. Not only do I believe that the calcium salts are deposited in this manner, but that the quantity and integrity of this deposit may vary according to general systemic conditions. We would thus have an explanation of the so-called softening of the enamel during general debility and later a re-hardening upon the recovery of the health of the body. I am not in the least dogmatic in this assertion, for I realize that the oral fluids could cause a variation in the hardness of the enamel under conditions of illness or health of the individual. However, I take the stand, from the analogy of the growth and nutrition of all other tissues in the body, that it is the blood plasma which calcifies the enamel. Why should nature introduce a special mode in the case of the enamel, when we know that this tissue is in intimate contact with the vital fluids which carry the elements for its calcification?

Sufficient evidence of the existence of the enamel matrix has been shown to-night in the form of photomicrographs; further proof will be given under the microscope. Each Fellow of the Academy will be able to view this matrix under a low binocular magnification and to manipulate it with a needle. It was this last proof which finally convinced J. Leon Williams of the presence of this matrix.

Proof has also been given concerning the connection of this matrix with the pulp of the tooth by means of the dentinal tubules. We may therefore logically conclude that it receives a slight amount of nourishment from this source and has a low vitality. I wish to make clear, at this point, my claims concerning the vitality of the enamel. I do not, by any means, claim that any rapid metabolic changes can take place in this tissue. The vitality of the enamel is on a par or even slightly below that of the epidermis. A study of the "prickle-cells" of this tissue under the microscope, discloses the fact that they are not in close apposition, but are separated by minute spaces or lymph clefts. The blood vessels terminate in the underlying connective tissue, the derma, but the blood plasma seeps into the lower layers of the epidermis by way of these lymph clefts, bathing these cells in lymph and thus supplying nourishment. The condition in the enamel may be regarded as being somewhat analogous. The blood vessels terminate in the pulp of the tooth. The blood plasma penetrates the dentin by means of the dentinal tubules and thus reaches the enamel matrix. In this tissue there is naturally no rapid current as in the blood vessels, but only a slow wick-like circulation. Under such conditions we can not expect to find a high form of life. Some clinicians expect the enamel to renew its growth, now that an organic matrix has been proven to exist or possibly even to find blood vessels in its structure, but this, of course is impossible. The enamel-forming organ is destroyed on the eruption of the tooth and therefore no change in *form* can take place in this tissue after the tooth has once penetrated the gum. The presence of blood, or even of a single red blood cell in the enamel is an utter impossibility for the diameter of the dentinal tubules leading from the pulp chamber to the enamel is 2–3 microns, whereas the size of a red blood cell is about 7 microns. These remarks have been considered advisable to emphasize the fact that the vitality of the enamel must be at the lowest degree.

And now, in a few words, I wish to consider the practical significance of the organic matrix in the adult enamel of the human teeth. During the past forty years, scientists have carried on heated discussions of this subject, not because it was a mere theoretical point, but because the presence or absence of such an organic matrix is of fundamental importance. I will endeavor to show the influence that the decision

of this question may have upon dentistry. As I do not want to tire you, I will be brief. I clearly understand that a number of the following points are purely hypothetical, but the reason for presenting them is to show their importance and the possibility of helping humanity, if they can be realized.

Let us suppose, as my experiments have proven to me, that the enamel is a vital structure possessing a very low degree of vitality. Our body with all its various organs forms a vital unit, and any weakening through disease or malnutrition of this unit will affect all its individual parts. Certain illnesses affect one organ or set of organs more than others. Typhoid fever, for instance, affects the intestines and indirectly the hair. And so it is my claim that *the teeth, including the enamel, may also be weakened by a general debility of the body.* If this becomes an established fact, it will be necessary for us to find out how we can guard against such a weakening. I clearly realize that this is looking far into the future, for we know very little about even the growth of the enamel. The products needed for its development are principally the calcium salts. Their absence apparently causes the development of a weak enamel. There may be an abundance of these in the food, yet through a derangement of the cycle of the ductless glands, the body is unable to assimilate them and thus to build sound enamel. In short, if we have once generally accepted the fact that enamel is vital, then more experiments will be undertaken to attempt to influence this tissue through diet or medication. What is most needed, is a more thorough knowledge of the activity of the ductless glands. In this way, there may be a gleam of hope of freeing humanity from dental caries.

Recognition of the importance of the pulp of a tooth seems to be steadily increasing. Years ago, it was considered to have done its duty when once the tooth was fully formed. To-day, this view no longer holds. The discovery of the various consequences of periapical infection has retarded the ruthless pulp extirpation of the past. If we now add to this the above mentioned function of the continued calcification of the erupted tooth, the importance of keeping the pulp in a healthy functioning condition is further accentuated.

If we admit that the enamel may become weakened by some constitutional disturbance, it is only natural that patients should be

warned to pay particular attention to the care of the teeth during its continuance and afterward. Under such conditions the most thorough cleaning may prevent the formation of newly carious cavities. Pregnancy is such a condition, which seems to be responsible for an added susceptibility to dental caries. Nature did not mean this to be a disease, for it is a normal physiological function, yet in the majority of cases the consequences to the mother are so severe that it can be regarded as a serious drain upon her system. Her teeth usually suffer to such an extent that the people, as a mass, have accepted the view that each child causes the loss of a tooth. It is not true that the lack of care of the teeth of the mother during this time is entirely responsible for this added susceptibility to caries, because both the expectant mother and the attending nurse know of this danger, and added precautions are used to keep the mouth in as clean a condition as possible. Yet the fact remains that dental caries appears more readily after such occurrences. We, as dentists, will only be able to help in this matter after the functions of the ductless glands have been still more thoroughly investigated. It is known that calcium metabolism is controlled by the activity of the ductless glands. As the ovaries belong to this cycle, it is significant that dental caries should be more prevalent during pregnancy. This fact alone may point to the correctness of my assertion that the enamel is a vital structure affected by the general health of the individual.

The celloidin decalcifying method has not only brought proof of the existence of an organic matrix, but has also shown its distribution. Another point, brought out by this method, which is even more valuable from a clinical aspect, is the marked difference I have found in the amount of organic matter in the teeth of various individuals. The enamel of many teeth shows but little of this matrix, whereas some contains a great amount. This difference may explain the variable tendency to dental caries in different individuals. Whether the enamel with the least organic matter is more resistant to dental caries, or vice versa, will have to be decided by further investigation. We need teeth for this purpose, with exact clinical history as to age, complexion, sex, tendency to caries, and color of the other teeth. It is on this point that the Fellows of the Academy can render aid by gathering such material. The teeth must not be allowed to dry.

I will be delighted to send anyone suitable containers and fixing fluid for this purpose.

The last matter to be considered is the hope of improving the condition of the enamel of erupted teeth by diet or medication. This possibility depends primarily upon the presence of the organic matrix, which allows fluids to permeate the enamel. Will we not be doing mankind a great service, if we succeed in strengthening poorly calcified enamel? Whether we will be able to do this by external medication through the saliva or by means of the general circulation, time will tell.

THE ALBUMINOUS CONTENT OF HUMAN ADULT ENAMEL[1]

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The steadily increasing spread of dental caries among the civilized nations of the world is engaging the interest of the philanthropist and health worker. Many investigations, from various angles, have been conducted in this important field. W. D. Miller's monumental work explained the phenomenon to a certain extent, in reference to the dentin, while G. V. Black showed that the initial stages of caries were prefaced by the formation of bacterial plaques. The manner, however, in which the bacteria penetrate the enamel, and the varying immunity and susceptibility of the teeth to dental caries, are only a few of the questions which are still unsolved. Our further progress in this field is primarily dependent upon advance in our knowledge of the histological structure of the enamel. We know comparatively little of the structural differences between sclerotic ("hard") and malacotic ("soft") teeth. How can we hope to comprehend the pathological changes which take place in the enamel during the initial stages of dental caries, when we do not know the normal constitution of this tissue. This statement may seem far fetched, but the following will prove it to be correct. Human enamel of adult teeth, having clearly marked striations of the rods as well as strongly developed Striae of Retzius, are considered as being poorly calcified and, therefore, more prone to caries. Yet we find both of these characteristics in the teeth of a number of animals which never suffer from dental caries.

The organic content of the enamel is a matter which has been most heatedly discussed during the past fifty years. It was considered that J. Leon Williams said the last word on this subject in 1896, that adult

[1] Read at the annual meeting of the International Association for Dental Research, Congress Hotel, Chicago, March 20, 1925.

enamel is totally inorganic in nature. Now however he has been convinced by the author's specimens that enamel contains an appreciable amount of organic matter. This organic matrix plays an important part in dental caries and may lead us to an explanation of the initial stages of this disease.

The preparation of specimens of enamel for examination under the microscope is accompanied by considerable difficulty. This tissue is probably the most difficult to prepare for microscopic examination. The high mineral content of this tissue causes considerable refraction of the light illuminating the ground microscopic specimen, thus obscuring its details and resulting in misconceptions concerning its minute structure. If, however, the mineral matter is removed in the ordinary way, the enamel falls to pieces and apparently disappears. Upon this disappearance, the claim was principally founded that enamel is purely inorganic. By the use of the author's celloidin decalcifying method, first published in 1905, the entire organic content of the enamel is retained, not only proving the presence of the matrix, but also showing its structure. The principal mass of this organic matrix is composed of the enamel-rod sheaths, which are delicate organic envelopes surrounding the enamel rods throughout their entire length.

A structure whose presence had not been before described is the enamel lamella. Cracks or checks in the enamel, caused by grinding the specimen, are numerous. Yet not all are checks, for the celloidin decalcifying method has demonstrated some of these to be filled with masses of compact organic matter, which the author named enamel lamellae. A more detailed description of these and other organic structures in adult enamel will be found elsewhere—this paper deals principally with the assertion of the presence of a matrix and the presentation of evidence regarding its chemical nature.

A modification of the celloidin decalcification method, suggested by J. Leon Williams, permits of even the tactile demonstration of the matrix of the enamel. Observers can manipulate this soft, sponge-like matrix with a needle and definitely remove the last doubt of its existence. J. Leon Williams and the members of the Association at the meeting held in New York, in December, 1923, as well as the members of the New York Academy of Dentistry, present at their meeting in New York in December, 1924, were convinced by this means of the presence of this mooted matrix.

Two indications that the residue of the enamel is albuminous were advanced by the author in 1905 and 1906; the results of decalcification and of the xanthoproteic test. In 1923, a third suggestion was given: the effect of incineration. Heat, when applied to the enamel, naturally consumes its organic content, leaving the mineral matter intact. Photomicrographs of specimens treated in such a manner are shown in a preceding paper (page 127), where it will be noted that the cement substance between the rods has been burned out, while the rods have maintained their form, thus indicating its organic nature. The final and conclusive proof, however, that the enamel of human adult teeth contains an albuminous matrix, is presented in the succeeding paper by Professor Gies.

ADDENDUM

Since the preparation of the preceding papers, considerable time has elapsed, and added proofs have further strengthened the conviction of the author. J. Leon Williams, in his Addendum to the two papers on Mottled Enamel, in the *Journal of Dental Research*, 1925, v, p. 189, states that he is now convinced of the presence of the organic matrix in the enamel. Upon this corroboration the author congratulates himself, for no investigator has focused his attention more intensely and more critically upon the enamel than J. Leon Williams. However, Dr. Williams does not go so far as to ascribe any active function to the organic matrix. Nevertheless, the author hopes to be able to convince Dr. Williams of this possibility also.

DIRECT EVIDENCE OF THE PRESENCE OF ALBUMINOUS MATTER IN ENAMEL[1]

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INTRODUCTION

Hypothesis encourages the investigator in his pursuit of truth, but skepticism keeps him from wandering into the attractive by-paths to error. Those who engage responsibly in research should weigh all conceivable alternative explanations for a given finding before accepting a conclusion. Presentations that may be unbalanced by unrestrained enthusiasm for a preconceived outcome, by partiality for a standing commitment, or by any influence, should be met by the coolness of impersonal critical judgment. Facts rather than fancies are the goal of scientific inquiry.

At the meeting where Dr. Bödecker presented the paper published on pages 117–130 of this issue, the present writer, in this skeptical spirit, called attention to two important omissions:

(a) It was not shown that the "organic" quality of the "matrix" could not have been derived, by reaction and replacement analogous in principle to those of petrification, from "organic" materials in the acid-celloidin mixture used for the decalcification, although in this process a substitute is believed to take the place of the main bulk of the enamel and to prevent disintegration of the delicate structure of the matrix (page 132). Such a derivation appeared to be a possibility though a remote one.

(b) It was not demonstrated that the matrix contained any distinctive constituent of protoplasm, or any "organic" product of proto-

[1] A preliminary report of these findings was published in the *Proceedings of the Society for Experimental Biology and Medicine*, 1924, xxii, p. 175; and also presented at the annual meeting of the International Association for Dental Research, Congress Hotel, Chicago, March 20, 1925.

plasmic activity, such as albuminous matter, to warrant the conclusion that the matrix exists in enamel as an "organic" structure.

The writer was aware of Dr. Bödecker's three reasons, as stated by him on page 141 of this issue, for his belief that the matrix contained organic matter; namely:

(1) Decalcification of enamel leaves a residue resembling soft tissue;

(2) The xanthoproteic test applied to the matrix is positive, suggesting the presence of protein; and

(3) Incineration causes spacing among the enamel rods, implying removal of the matrix by combustion.

These conditions are merely suggestive, however, and are not conclusive evidence, for each is open to more than one interpretation. Thus, (1) the significance of the first point in evidence is rendered uncertain by the reasonable doubt expressed in paragraph (a), above. (2) The xanthoproteic test is not a reliable one for albuminous matter, since many non-protein substances respond to it. (3) The effects pictured on page 127, as consequences of incineration, might be due to removal of water, or to decomposition and volatilization of unstable inorganic substances in the prisms or in the interprismatic matter, or both; or might represent a uniform shrinkage of the enamel rods owing to a special inorganic condensation or transformation at the high temperature of ignition. If such burned enamel had been subjected to the decalcification process, and no organic matrix had then been recovered, this finding, interpreted in the light of the others, would have been very impressive.

Without attempting a study of the problem suggested in paragraph (a), above, an effort was made to remove the doubt indicated in paragraph (b), by determining whether the enamel matrix contains protein material. This was done, in Dr. Bödecker's presence, by applying tests directly to typical pieces of the matrix that had been prepared, by Dr. Bödecker, by his usual procedure continued for the customary length of time. Portions of the reagents he used in the preparation of the matrix particles were tested for protein impurities, but with negative results.

PROCEDURE AND RESULTS

Human teeth, after immersion for several days in 10 per cent formalin solution, were sectioned transversely through the crowns. The

sections were ground to the thickness of about 1 mm. or less; dehydrated in ethyl alcohol; decalcified by Bödecker's process in a mixture of methyl alcohol, nitric acid, and celloidin; freed from celloidin with a mixture of equal parts of ethyl alcohol and ether, and kept in ethyl alcohol. Throughout this procedure the residual portion of the enamel retained approximately the original outlines. Under a lens of low power, a particle of the soft yellowish-white enamel residue, about a millimeter wide and several millimeters long, after being gently teased from a section prepared in this way, was transferred carefully with a pipette to water, in which it was soaked and washed for the removal of soluble extraneous matter; and then pipetted cautiously to a microscope slide, where the identity of the material was confirmed by Dr. Bödecker, and the absence of dentinal admixture established. At this stage the particle was slightly acid in reaction to litmus.

The fragment of soft enamel residue, which remained intact during these manipulations, was then treated on the slide with a few drops of Gies's reagent for Piotrowsky's ("biuret") test for protein. Gradually the particle under microscopic examination acquired a lavender tinge of uneven intensity, the coloration ultimately becoming evident to the naked eye. In this respect it behaved like a small particle of coagulated egg-white. This result was also obtained with incompletely decalcified specimens. The Molisch test for carbohydrate, and the ammoniacal silver test for aldehydes, applied to other pieces, were negative, indicating that the positive result of the biuret test was due neither to a reducing substance derived from the celloidin nor to retained formalin. This general finding was directly corroborated by the fact that pieces of the enamel residue, when gently warmed in Millon's reagent, gave the red response that is typical of insoluble protein matter.

GENERAL CONCLUSION

Since no insoluble material except a protein mass gives the biuret test under the severely exclusive conditions of this experiment, the result, repeatedly obtained, presents conclusive chemical evidence of the presence of protein in enamel, and of the occurrence there of true protoplasmic ("organic") matter, in accord with Bödecker's prior deductions to that effect on histological grounds.

DISCUSSION

The foregoing proof that the matrix contains albuminous matter did not include a determination of the nature of the contained protein. It might be keratin, the chief protein constituent of all other ectodermal structures in the higher animals, but this is merely a reasonable guess. An attempt will be made to ascertain the quality and relationships of the protein. Pending such a determination, any discussion of the organic matrix as a factor in the nutrition of the enamel must remain speculative.

The following facts, among many, have a significant bearing on a solution of the problem of nutrition in enamel.

1. The smaller the structure in which nutrition or metabolism occurs in a mammalian tissue, the larger the proportion of the selective cellular nuclei involved; but no cellular nuclei have yet been found in the enamel matrix.

2. It has not been shown that the organic matrix itself is not densely mineralized *in situ* in the enamel.

3. Movement of water in the enamel (as in a lamp wick, page 135) might occur wholly by capillarity or osmosis, and without any selective character.

4. Movement of substances (in solution) by capillarity or osmosis may be beneficial, indifferent, or destructive, without being nutritional.

5. Nutrition is a process of selective acquisition in the structure that is being nourished. It involves a tripartite procedure—assumption, transformation, and rejection of materials—resulting in renewal of mass and in removal of waste. It is not a one-way traffic, but a process of come and go.

6. The enamel protein is stained deeply by trypan blue. Some years ago the present writer demonstrated, in dogs, that *while enamal is being produced, trypan blue, after its injection into the circulation, is absorbed into the enamel*, and is permanently retained; but that after enamel has been formed, trypan blue does not pass into it from the circulation, although the pigment enters the dentin.[2] Since injected trypan blue is removed from all stained parts of the living body except dental enamel (after its passage into enamel under the special

[2] Gies: *Journal of the National (American) Dental Association*, 1918, v, 529.

conditions just stated), it is probable that the degree of true *nutritional* transformation, as distinguished from simple mechanical change, in enamel *after its production*, is very slight if not wholly negative.

7. If the enamel matrix is entirely inert chemically and devoid of nutritive influence, it is possible nevertheless that physical (mechanical) transmission of ions and molecules on or in its framework, distinct from physiological (selective) movement but inaugurated or controlled by conditions external to the matrix, might account for important effects on the enamel. Changes of this character appear to be the kind that Dr. Bödecker has projected but which he terms nutritional.

Dr. Bödecker's very significant findings may lead to important discoveries, especially as to the origin and the prevention of dental caries. Such developments will be accelerated rather than retarded by searching scrutiny of all hypotheses regarding the function and dynamic relationships of the organic matrix.

REGIONAL ANESTHESIA IN DENTAL AND ORAL SURGERY[1]

A Plea for Its Standardization[2]

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Recent developments of surgical technic have broadened the avenues of all endeavors in this field, and have created a demand for better anesthesia. The choice of the methods of anesthesia has attracted the attention of the progressive surgeon, and, because of its obvious advantages, regional anesthesia has asserted its superiority in many fields of surgical practice. The scope of the dental and oral surgeon's activities and the topography of his operative field are special inducements to the use of local anesthetics. The extent of the operative procedures that may be performed in the oral cavity, their nature, attendant circumstances, and post-operative aspects, all contribute to the adoption of regional anesthesia as the standard method.

Regional anesthesia is the temporary interruption of sensory nerve conductivity. It is also called block anesthesia, conductive or conduction anesthesia. It is best accomplished by injecting the nerves at a distance from the operative field. It results in a wide area of insensibility and a marked degree of muscular relaxation. In a majority of cases, the anesthesia lasts for from one and a half to two hours, and is followed by a long period of analgesia, which tides the patient over the acute stage of post-operative pain. It is thus distinguished from local infiltration.

The advantages of local, terminal, or infiltration anesthesia are well known. Its use is widespread in dentistry and oral surgery, but its limitations are such that it is unreliable for many operations. The

[1] Read at a meeting of the First District Dental Society of the State of New York, at the New York Academy of Medicine, November 2, 1925.

[2] The author makes a plea for the adoption of regional anesthesia as a standard method. He uses "standardization" in this sense only.—(*Ed.*)

anesthesia produced by local infiltration is superficial and of relatively short duration. It is therefore unreliable for elaborate procedures involving the deep structures, especially the bone. The effect of local infiltration is limited to the infiltrated zone, and therefore is insufficient for operations involving wide areas. Its use in the oral cavity is contra-indicated in local septic conditions, and it cannot be employed in cases of trismus. Regional anesthesia, that is, blocking the nerves individually and injecting them at selected sites far away from the operative field, obviates all of the inconveniences of local infiltration. It can be accomplished by the extra-oral route as well as by the intra-oral route with equal facility, and enjoys the favor of many surgeons.

Of the nerves that interest the dental and oral surgeon, two and only two need his earnest consideration; namely, the maxillary and mandibular nerves. These two divisions of the trigeminus distribute themselves to definite and distinct territories which bear little or no relationship to one another. The maxillary nerve is entirely sensory and supplies the upper jaw, including the hard palate, soft palate, teeth, gum tissue, mucous membrane, upper lip, and a wide portion of the cheek. It also takes part in the innervation of the nasal pyramid and lower eyelid. The mandibular nerve is a mixed nerve that supplies the lower jaw with sensory elements and the masticatory apparatus with motor function. The cutaneous territories of these nerves may overlap each other differently in different individuals; but never has a branch of either nerve been found in the oral structures controlled by the other. Again, their position with regard to the pterygoid process is so constant, and the direction of their paths so uniformly divergent, that the blocking of the one does not influence the functions of the other. Such anatomical features carry with them the full measure of accuracy in the results to be expected by the injection of any or both of these nerves. They bestow on the regional method the highest degree of precision.

The *maxillary nerve* may be blocked in many ways. *By the intra-oral route*, (*a*) the needle can be passed through the posterior palatine foramen up the palatine canal into the sphenomaxillary fossa. This technique has already been described in connection with the injection of the sphenopalatine, or Meckel's ganglion, for the treatment of neuralgia. (*b*) The needle may reach the same location by following

the outer surface of the bony structures of the upper jaw. In this case it is introduced along the line of junction of the pterygoid process of the sphenoid bone with the tuberosity of the maxillary bone. (*c*) The needle may be passed obliquely along the outer surface of the maxilla until it reaches the spheno-maxillary fossa. The last technique (*c*) is the most popular, for the maxillary block and for the posterior superior dental block. *By the extra-oral route*, also called the zygomatic route, (*d*) the needle is passed just below the middle point of the zygomatic arch, through the masseter muscle, which obliterates the sigmoid notch of the ascending ramus of the mandible. It is introduced transversely towards the base of the pterygoid process as a deep landmark, after which it is passed frontwards into the spheno-maxillary fossa. (*e*) The needle may also be inserted at the angle formed by the anterior border of the coronoid process of the mandible and the malar bone. It is then advanced along the lateral and posterior surfaces of the maxilla. (*f*) A third site of puncture is above the zygomatic process of the malar bone. Of these the first technique (*d*) is the most practical, but knowledge of the others may be of service in particular cases.

The *mandibular block* may be induced by passing either through the oral cavity or by the extra-oral route. *By the intra-oral route*, (*g*) the needle is inserted in the mucous reflection opposite the coronal surface at the apex of the second upper molar tooth, and is carried backwards and upwards towards the infratemporal plane close to the base of the pterygoid process. The nerve is injected at its exit from the foramen ovale. *By the extra-oral route*, (*h*) the needle may be introduced through the cheek at a point 3 cm. lateral to and 1 cm. above the angle of the mouth, and pushed towards the infratemporal plane, then to the foramen ovale. (*i*) The zygomatic route (*d*) of the *maxillary block* may also be used for the mandibular block, the needle being directed towards the posterior aspect of the base of the pterygoid process. All of these procedures (*a–i*) have been described in detail elsewhere. Their study is rendered easy by dissections and practice on the cadaver. The abundant material supplied by the clinics of exodontia and oral surgery adds clinical experience to laboratory practice. Regional anesthesia can be mastered thoroughly without difficulty and unnecessary loss of time. The use of adequate

instruments for the accomplishment of each procedure renders the technique easier and more accurate.

The inferior dental block and posterior superior dental block are procedures with which the profession is thoroughly familiar. The infra-orbital, mental, and palatine blocks are also popular, the oral route being almost exclusively used as the route of choice. The blocking of the maxillary and mandibular nerves at the base of the skull has had but limited clinical application, but the growing tendency of the oral surgeon to increase the range of his operations makes it necessary to widen also the scope of his anesthetic procedures. The nerves are blocked at a higher level, nearer their points of origin, and the extra-oral route is used as well as the oral route. The blocking of the cervical nerves extends the anesthesia of the floor of the mouth to the submental region, and gives added facilities for operations necessitating an extra-oral route of approach or drainage. It is also of great value in plastic surgery.

Regional anesthesia is the method of choice in dental and oral surgery because most of the surgeon's work is done in the office, and his patients walk in and are expected to walk out. His surgical procedures are restricted to a particularly favorable region of the body. The nerves supplying its structures are easily blocked owing to unvarying and accurate landmarks. Novocain, the anesthetic drug of choice, is harmless. It does not interfere with the general circulation, and it thus leaves intact the vital organs of the body. The induction of regional anesthesia is so simple and safe that it gives birth to great confidence and self-control—the anesthesia is so perfect and its duration so long that the practitioner can take all the time he needs for his operation without fear of being disturbed by a premature recovery or a respiratory failure. If necessary, regional anesthesia can be repeated as often as necessary at the same sitting without the slightest inconvenience to the patient.

The dental and oral surgeon's practice involves many delicate procedures, such as the surgical removal of teeth, extraction of impacted third molars, treatment of fractures, and many others, which are time consuming and demand great delicacy and precision of technique in their accomplishment. They are best performed under regional anesthesia, and practice based on this type of anesthesia has completely changed their clinical aspect.

The particular advantages of the oral route in office practice are too well known to require discussion, but there are cases in which the extra-oral route assumes a higher practical value. The injection of the maxillary nerve in the sphenomaxillary fossa is associated with that of the sphenopalatine or Meckel's ganglion, and is followed by a complete anesthesia of the upper jaw. For multiple extractions, for instance, this single block replaces with greater advantage the many superficial and deep injections which are occasionally made in vain to block the bicuspids and first molar. The zone of anesthesia must always be adequate to the nature and extent of the surgical manipulation. This is sometimes best afforded by using the extra-oral route, particularly when there is insufficient exposure of the oral cavity. When anatomical or pathological conditions do not justify the injection of the nerves by the oral route, they should be blocked by the extra-oral or zygomatic route. Familiarity with both routes gives better judgment and greater operative facilities. Many patients who otherwise would have been sent to the hospital are thus treated in the office; and, with increased experience with the regional method, office practice becomes broader, easier, and safer.

In the hospital where more serious operations are performed, it is customary to dull the mentality of the patient before the operation. Morphin and scopolamin are combined in weak doses and given hypodermically one hour before the operation. They are used to blunt consciousness, but not to abolish it. The patient is thus placed in a very obedient mood, which in some instances is carried to a stage approaching that of twilight sleep. This is a semi-waking condition which, associated with regional anesthesia, affords increased operative facilities, while the characteristic features of the method remain intact. Consciousness is maintained while the patient stays indifferent to the world around him. He is able to cough and expectorate, and will always expel any foreign body that might approach the organ of respiration. The association of narcotics with regional anesthesia creates the most favorable conditions for extensive manipulation, and avoids many post-operative complications. It is the ideal method for operations performed in the hospital.

The only contra-indications to the use of regional anesthesia are the exceptional cases of anatomical deformities and those in which the

focus of infection is at the site of puncture or that of injection. Pathological conditions of the oral cavity very seldom contra-indicate the use of regional anesthesia. Although preventing access to the mouth or rendering it difficult, trismus is not a contra-indication to the induction of regional anesthesia. On the contrary, patients are greatly benefitted by its use. The mandibular block at the foramen ovale, by the extra-oral route, immediately influences the cause of the trismus, and creates favorable conditions for its automatic relief, unless the chronicity of the disease renders its reduction impracticable. If it is absolutely necessary to expose the oral cavity, the injection of the mandibular nerve by the extra-oral or zygomatic route is of the highest practical value. As a result of this nerve block in abolishing pain, the trismus may spontaneously subside partially or completely; and, in lowering the tonus of the masticatory muscles, surgical manipulation to obtain better exposure becomes easy, safe, and sure. There is thus very little risk, if any, of rupturing part of the soft structures of the masticatory apparatus or of dislocating the mandible. Anatomical distortions need individual consideration at the time of the injection.

Children and patients of the extremely nervous type are said to be bad subjects for local anesthesia. In our experience there is much exaggeration in the alleged difficulty of managing these classes of patients. Children generally behave themselves well in the chair. It is only a matter of knowing how to win their confidence. The number of extremely nervous patients can be reduced to a very low percentage by simply assuring them that the operation will be performed painlessly. In handling the more refractory with gentleness and skill this percentage is again reduced to infinitesimal figures.

The patient's demand for general anesthesia does not justify its use, since the patient knows as much of the methods of anesthesia as of the particular treatment or operation he needs. What he really wants is a painless operation. He should simply be advised in the matter and convinced of the advantages of the regional method. Very few patients refuse to follow the advice of the man in whom they have placed their confidence.

The practice of regional anesthesia in dental and oral surgery is intimately associated with the practice of this specialty. It does not require the presence of a qualified assistant. It is part and parcel of

the surgeon's work. Its superiority is particularly due to the fact that it can be accomplished before the operation is begun and does not interfere with the surgical procedure. Its clinical significance is evidenced by its recognition in the schools as part of the surgical training.

CONCLUSIONS

The nature and extent of the dental and oral surgeon's work are special inducements to the use of local anesthetics: his practice is almost exclusively office work, and his patients are ambulatory.

Local infiltration has decided advantages for minor operations, but it has also great limitations and many contra-indications.

Regional anesthesia, nerve blocking, conductive or conduction anesthesia, obviates all of the inconveniences of local infiltration and widens the scope of operations performed in the oral cavity.

Regional anesthesia is easily and quickly accomplished. The anesthesia is of long duration and allows the surgeon to take all the time he needs. It is safe and can be repeated as often as may be necessary at the same sitting.

Maintenance of consciousness is of the highest clinical value in dental and oral surgery, because the operations are performed at the entrance to the air passage.

Great anatomical distortions and local infections at the site of puncture, or at that of injection, are contra-indications to the use of regional anesthesia.

Regional anesthesia is a scientific method based on surgical principles. It can be mastered by the student during his college years. The practitioner can familiarize himself with it in a relatively short period of time.

Regional anesthesia gives confidence and self-control with complete command of the operative procedure. It increases office practice, and renders it easy and safe both for the patient and the surgeon.

Regional anesthesia is a tool in the dental and oral surgeon's armamentarium—the most precious tool that contributes to the success of his practice.

5 East 53rd Street.

DISCUSSION

Bissell B. Palmer, Jr., D.D.S. (New York City): By way of introduction, may I be permitted to say that I had only a synopsis of the paper when writing my discussion, and I find that I have misunderstood the intent of Dr. Labat's paper. I noted the sub-title: "A plea for its standardization," and understood it to be a plea for the standardization of technic. Dr. Labat, however, is making a plea for regional anesthesia, as a standard method in dental and oral surgery, so you will see, as I read, that my conception of Dr. Labat's paper was wrong. I hope, however, that the points which I shall endeavor to make may prove of value in rounding out the presentation of this subject.

Dr. Labat has spoken of the selection of the anesthetic, and the ability of the operator to gain the confidence of his patient by the assurance that there will be no pain. I can understand that this may be possible in general surgery, but I think that if Dr. Labat were practicing dental surgery, he would find himself confronted by a situation having a different psychological aspect. It frequently happens that a woman who does not dread bearing twins, will balk at the thought of having a tooth removed. A man will hold out his arm for the surgeon to incise perhaps to the bone, without wincing, but will not allow the dental surgeon, without a great deal of persuasion, to touch one of his teeth. My theory is that this is not due to cowardice, for these same patients who cannot bear the thought of having a tooth removed will allow you to perform almost any other operation. Some men have won medals for bravery in the World War, and yet they will not let a dentist touch their teeth. It is based, I believe, on the fact that our ancestors went through so much suffering before general anesthesia or regional anesthesia was discovered, that it has left the human race in a condition of mind in which they cannot bear the thought of undergoing dental operative pain.

As to preliminary dosage: if we could give patients in our offices a preliminary dosage of a sedative before resorting to regional anesthesia, I think we would overcome many of its disadvantages. We cannot do that in sufficient strength, because the patient must leave the office soon afterwards. It does not seem safe to give them any drug which through its prolonged effect may cause them distress after leaving the office.

Regional anesthesia is happily another on the ever increasing list of subjects which the medical and dental professions can discuss on common ground. It has been a pleasure to listen to Dr. Labat's carefully constructed paper in which he has built up a strong argument in support of the use of regional anesthesia in oral surgery.

Too often in our professional meetings the discussor of a paper arises, and after complimenting the essayist in graceful and well chosen words, proceeds to emphasize a few of the main points brought out in the paper. The speaker has always believed that the value of a discussion lies not in agreement but rather in constructive disagreement with the essayist. Only in this way can an audience be given the different opinions so essential to the making of a logical analysis and the forming of a scientific conclusion. It is this conclusion, carried away for practical application by the individual, which creates the value of both a paper and its discussion.

Everything complimentary which Dr. Labat has said about the merits of regional anesthesia I second most enthusiastically. The development of this sensation-free method of operating is unquestionably of divine inspiration and a God-given boon to mankind. In its place and where indicated, regional anesthesia is one of the very greatest contributions to modern surgery. For several years past, however, I have taught, written, and preached against the false doctrine that there is "one best anesthetic" for *all* cases in oral surgery. I have just as forcibly maintained that there *is* a "best anesthetic" for *each* case in oral surgery. As the years go on, observation causes me to become more and more emphatically confirmed in this belief. While it is not my impression that Dr. Labat advocates the use of regional anesthesia in practically all cases, the differential selection of the anesthetic is so closely related to the subject matter of his paper that I shall confine my discussion to that phase of the subject.

The oral surgeon who limits himself to operating with regional anesthesia, and who has not at hand the facilities for administering a general anesthetic, quite understandably perceives no value in the use of a general anesthetic, just as the operator who uses general anesthesia exclusively can see no value in regional anesthesia. Both these surgeons are incorrect and narrow in their attitudes, and we must try to advance beyond this point in oral surgery. Let our selection of the anesthetic be based not upon the ability of the operator to administer but one type, not on the basis of how many patients can be operated within a stated period, not on the basis of an anesthetic hobby of the operator, but rather let it be based upon the sole consideration of what is the best anesthetic for the case at hand. In our analysis of the best type of anesthetic for a given case, we must keep in mind three points: (a) safety for the patient; (b) the practicability of the anesthetic in consideration of the operation to be performed; and (c) the temperament of the patient.

For the past several years I have kept accurate statistics covering the

use of local and general anesthetics in my own practice. While this is not the time to report these figures in detail, it is a notable fact that for the past few years both types of anesthetics have occupied a balanced position in my practice. The fact that I use each anesthetic for about fifty per cent of my operations may possibly make interesting to you a brief outline of the factors governing my choice. Taking the three factors mentioned earlier as deciding the choice of the anesthetic, I shall first touch on the general condition of the patient and safety. Everything else being equal, I prefer a general anesthetic for the following types of cases: Neurotics, cardiacs, and pregnancies. The *neurotics* dread the needle puncture of local anesthesia just as they dread every step of the operation. The fact that there is no pain in each successive step does not convince this type of patient that there will not be pain in the next one. The imagination of such a patient runs riot, and I have seen numerous cases in which an operation under perfect local anesthesia terminated in severe psychic shock with some symptoms lasting for a number of days. These patients plead for a general anesthetic and when practical they should be given it. This same general psychological factor applies to children. I make a practice of administering nitrous oxide-oxygen to patients under fourteen years of age. Strange as it may seem to many, I have seen much less distress in *cardiacs* under general anesthesia than in similar cases under local anesthesia. In speaking of general anesthesia at this time, I refer to a nitrous oxide-oxygen administration. These patients tolerate a smoothly given gas-oxygen, but they should be carried along lightly with a consistently high oxygen percentage; and should never be pushed to the point of labored or obstructed breathing, or cyanosis. The *pregnant patient* does beautifully under gas-oxygen. Despite the fact that I have administered this anesthetic to patients in every stage of the term, I have yet to see a case in which the patient has shown any ill effects from the anesthetic.

In considering our choice of procedure as based on the local conditions presented, I favor general anesthesia in cases of cellulitis, trismus, or any wide-spread infection which would make it impossible to inject the anesthetic locally without passing the needle through septic tissue. On the other hand, I favor local anesthesia as against gas-oxygen for cases of removal of impacted teeth, excementosed teeth, difficult resections, alveolectomy, or any other time-consuming operations where it is also of great advantage to have a comparatively bloodless field. I likewise lean to local anesthesia in cases where there is considerable porcelain in the mouth in the nature of tooth restorations. It is very easy to damage such teeth under general anesthesia and it should be a consideration in making our choice.

The question of the temperament of the patient has deliberately been placed third in importance in selecting the anesthetic, because this factor should be given weighty consideration in the event only that neither the general condition of the patient nor the local condition to be operated presents an arbitrary and compelling choice. There are many patients who dread losing consciousness just as there are many who dread not losing consciousness during an oral surgical procedure. If the end result will be as favorable with a local as with a general anesthetic, I favor allowing the patient to select the method of anesthesia.

If the proposed operation gives indications of lasting over twenty minutes, and if for any reason local anesthesia is contraindicated, I hospitalize my patient. While for years I gave nitrous oxide oxygen for long operations in the office, some lasting for forty-five minutes or more, I feel today that it is not conservative, safe practice. Subsequent to prolonged anesthesia no patient should be sent home after a short recovery period.

I am often asked whether there is apt to be greater pain and slower healing following the use of regional anesthesia than after general anesthesia. My answer is that everything else being equal I have detected no appreciable difference between the two methods. The common experience to the contrary is based on two causes. First, the local anesthetic has been injected into tissues the condition of which contraindicated its use. Second, the technic has been faulty. Patients who complain of comparatively more pain following the use of local anesthesia fail to consider the fact that many operators use the general anesthetic for short, simple cases where naturally there would be but slight after-pain, and reserve for local anesthesia those difficult operations which result in a painful aftermath regardless of what anesthetic may be employed.

Without taking any more of your time may I state that the purpose of my discussion has been to urge the use of discretion and judgment, and not merely habit in choosing the anesthetic.

Aaron Goldman, D.D.S. (*New York City*): One objection to general anesthesia, pointed out this evening, was the idea that it makes it necessary to perform the operation rapidly, and that the extraction or surgical operation must be done in a slipshod manner. I do not agree with this view. The ideal general anesthetic, with the use of synergists, gives one sufficient time to perform an operation with ease. Thus with a combination of ethylene, nitrous oxide, and oxygen, plus the use of vapor synergists, one can maintain anesthesia for a sufficient length of time to perform a surgical operation or the extraction of a number of teeth. In our experience for the

last fifteen years with (1) nitrous oxide alone, (2) nitrous oxide and oxygen, (3) nitrous oxide and oxygen, with vapor synergists, (4) ethylene and oxygen alone, and with vapor synergists, (5) acetylene, nitrous oxide, and oxygen, we find that the following technique with nitrous oxide, acetylene, and oxygen is far superior to that for any known general anesthetic.

Technique. The nasal inhaler is adapted and the mouth prop inserted. To disguise the odor we commence with nitrous oxide. After about ten inhalations of nitrous oxide we turn on acetylene and oxygen; thus we give a combination of nitrous oxide, acetylene, and oxygen. We administer 20 per cent of oxygen at the very beginning, after the acetylene has been turned on. The patient loses consciousness in one minute. The oxygen is then increased to 27 per cent. The towel over the mouth is removed, the pharyngeal pack is carefully inserted, the area to be operated is carefully examined, and the necessary work is performed slowly and in a surgical manner. As a rule the longer the anesthesia, the less the amount of acetylene used and the more of oxygen administered. The color of the patient remains pink throughout the anesthesia. In a series of over 2000 acetylene-oxygen administrations, the length of administration varied from 3–45 minutes; ages 4–89 years.

The advantages in the use of acetylene-nitrous oxide and oxygen may be summarized as follows:

1. Rapid induction; average patient, one minute.
2. Ease of maintenance.
3. The oxygen content of the blood remains normal throughout the anesthesia—the patient's color is always good. Signs of cyanosis or asphyxia are invariably absent—the patient appears to be in sound, healthy pleasant sleep.
4. Admission of air by way of the mouth will not interfere with the anesthesia.
5. Rapid awakening.

Gauss and Wieland report favorable results for abdominal operations with acetylene and oxygen. They obtain good relaxation of the abdominal muscles. In our work we find that with acetylene and oxygen we get good relaxation of the masticatory muscles, so that when extraction of teeth is indicated on the right and left side of a patient, we can easily shift the mouth prop from one side to the other.

Acetylene and oxygen is beyond the experimental stage at the present time. We are convinced that it will replace the other general anesthetics within the coming five years. When the Executive Committee of the First District Dental Society invites us to do so, we shall be pleased to present the subject in a practical and scientific manner.

Dr. Labat (in conclusion): I greatly appreciate the discussion of Drs. Palmer and Goldman. My intention in making a plea for the standardization of regional anesthesia, as was seen by the paper, was not to ask you to use regional anesthesia exclusively. Standardization does not mean that it should be used exclusively. I simply say it should be adopted as a standard method, because of many reasons which I have already explained to you; but I have also stated there are contra-indications, and in those conditions general anesthesia should be used.

My contention in making a plea for standardization is that the dentist, or the oral surgeon, in his office is ordinarily his own anesthetist, and it is safer to use local anesthesia, and when necessary regional anesthesia, in order to extend the field of operation, when he is alone; but if he has an expert anesthetist with him, it is all right for him to use the method he thinks best.

Dr. Palmer says the condition of the patient should be considered. Where should it be more considered than in general surgery? I did not want to include the objections to general anesthesia in general surgery. The fact that in dental and oral surgery the operations are performed in the mouth, at the entrance to the air passages, is the chief objection to the use of a general anesthetic. Besides, it is very seldom that a dentist investigates the general condition of the patient. I have consulted dentists, and was never asked whether I was a cardiac, or afflicted with hyperthyroidism, or any other abnormal condition. Many practitioners do make general examinations to determine the condition of their patients, but I am under the impression that most dentists do not. If they follow this practice they should refrain from using general anesthesia. Injections of 150 cc. of a 1 per cent solution of procaine, and even 500 cc. of a 0.5 per cent solution do no harm, even in cardiovascular and renal conditions. Regional anesthesia does not interfere with the general condition, and the patient leaves the operating room after one and a half or two hours without any appreciable systemic effect. Therefore, the injection of from 5 to 10 cc. of a 2 per cent solution of novocain for oral operations is absolutely safe. The condition of neurotics, of course, cannot be helped in the office. They cannot be given any narcotics; but in the hospitals, for major operations, they are. Pregnancy is not a contra-indication to local or regional anesthesia. On the contrary parturients are often benefitted by its use. We all have to apply the best anesthetic at hand for the individual, but we always consider local methods preferable to general methods. I must disagree with Dr. Palmer in his statement that a patient would have anything done to him, even a laparotomy, and could see his stomach cut in two, but could not have a tooth extracted, while in a state of consciousness.

The injection of great amounts of hypertonic or of hypotonic solutions —even of distilled water—has frequently resulted in deleterious after-effects at the site of the injection. In many cases there is after-pain, and sometimes pain at the time of injection. We have seen sloughing at the site of injection, due to the injection of pure water, or of hypotonic or hypertonic solutions; and we here speak in terms of sodium chloride. With 0.9 per cent sodium chloride solution the anesthetic effect seems more pronounced; the novocaine stays *in situ* for a time, being gradually absorbed into its constituent elements.